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The Density of Capelin (Mallotus villosus Müller) Eggs on Spawning Beaches in Conception Bay, Newfoundland

Christopher T. Taggart and Brian S. Nakashima

Science Branch
Department of Fisheries and Oceans
P.O. Box 5667
St. John's, Newfoundland A1C 5X1

November 1987

Canadian Technical Report of Fisheries and Aquatic Sciences No. 1580

Fisheries and Oceans / Pêches et Océans

Canada

Canadian Technical Report of Fisheries and Aquatic Sciences

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THE DENSITY OF CAPELIN (MALLOTUS VILLOSUS MÜLLER) EGGS ON SPAWNING BEACHES IN CONCEPTION BAY, NEWFOUNDLAND

by

Christopher T. Taggart

Departmenet of Biology

Dalhousie University

Halifax, Nova Scotia

B3H 4J1

and

Brian S. Nakashima

Science Branch

Department of Fisheries and Oceans

P.O. Box 5667

St. John's, Newfoundland A1C 5X1

Cat. No. Fs 97-6/1580E ISSN 0706-6457

Correct citation for this publication:

Taggart, C. T., and B. S. Nakashima. 1987. The density of capelin (Mallotus villosus Müller) eggs on spawning beaches in Conception Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1580: iv + 16 p.

CONTENTS

ABSTRACT

Taggart, C. T., and B. S. Nakashima. 1987. The density of capelin (*Mallotus villosus* Müller) eggs on spawning beaches in Conception Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1580: iv + 16 p.

Beach-core samples were collected in 1983 at 16 spawning beaches located around and along 75 km of the western and southern periphery of Conception Bay, Newfoundland. Spawning beach area was highly variable, ranging from 389 m^2 to 12127 m^2 and averaged 3268 m^2. Core depths were normally distributed, ranged from 7 to 16 cm, and averaged 11.9 cm. Analysis of variance showed no significant difference in core depth among three (high, mid, and low) intertidal zones. Egg density averaged $46/cm^3$ ($3-127/cm^3$) and showed a bimodal distribution (modes at 40 and $110/cm^3$). Intertidal zone density estimates were not significantly different. Depth standardized areal density estimates were log-normally distributed. Multivariate linear regression analysis revealed no significant relationships between various measures of egg density and beach orientation, latitude and beach area. Total egg deposition estimates (eggs/beach) ranged from $\sim 1 \times 10^9$ to $\sim 80 \times 10^9$ and were log-normally distributed. The geometric average estimate of deposition was 8.8×10^9 eggs/beach. An apparent dome-shaped relationship between deposition and beach orientation indicates that maximum egg deposition occurs on beaches oriented toward the N/NE. There was an apparent grouping of beaches by latitude, each showing a general decline in deposition with latitude within each group.

RÉSUMÉ

Taggart, C. T., and B. S. Nakashima. 1987. The density of capelin (*Mallotus villosus* Müller) eggs on spawning beaches in Conception Bay, Newfoundland. Can. Tech. Rep. Fish. Aquat. Sci. 1580: iv + 19 p.

En 1983, on a effectué un échantillonnage par carottage de 16 plages-frayères couvrant 75 km du littoral méridional et occidental de la baie de la Conception (Terre-Neuve). La superficie des frayères variait fortement alant de 389 m^2 à 12 127 m^2 (moyenne: 3 268 m^2). La longueur des carottes suivait une distribution normale, variant de 7 à 16 cm (moyenne: 11,9 cm). Une analyse de la variance n'a pas révélé de différences significatives entre les longueurs de carottes prélevées dans trois zones intertidales (position élevée, médiane et basse). La densité des oeufs allait de 3 à 127 oeufs/cm^3 (moyenne: 46 oeufs/cm^3) et montrait une distribution bimodale (40 et 110 oeufs/cm^3). Les densités estimatives n'étaient pas significativement différentes selon les zones intertidales. Les estimations de la densité superficielle normalisées en fonction de la profondeur suivaient une distribution lognormale. Une analyse de la régression linéaire multifactorielle n'a pas révélé de relations significatives entre les divers dénombrements de la densité des oeufs et l'orientation de la plage, la latitude et la superficie de la plage. Des etimations du nombre total d'oeufs pondus (nombre d'oeufs/plage) varient d'environ $\approx 1 \times 10^9$ à $\approx 80 \times 10^9$ oeufs; ces estimations suivent une distribution lognormale. L'estimation rétrocalculée de la moyenne géométrique du nombre d'oeufs pondus se situe à $8,8 \times 10^9$ oeufs/plage. Une courbe en forme de cloche montrant une relation entre le nombre d'oeufs pondus et l'orientation de la plage porte à croire à une ponte maximum sur les plages orientées vers le nord-nord-est. Il existe un regroupement de plages selon la latitude où chacun montre une baisse du nombre d'oeufs pondus selon la latitude des plages.

INTRODUCTION

Fully mature capelin (Mallotus villosus) observed in eastern Newfoundland between Cape Freels and Cape St. Mary's (NAFO Div. 3L) migrate inshore in early summer to spawn on beaches along the coast. One source of annual spawning variation on these beaches can be attributed to temporal variation in the size and the geographic occurrence of capelin schools (Nakashima 1985, 1986). The objective of this study was to estimate capelin egg deposition on sixteen spawning beaches in Conception Bay and to identify other sources of variation in egg deposition among the spawning beaches.

METHODS

BEACH SAMPLING

Beach-core samples were collected at 16 spawning beaches located along and around the western and southern periphery of Conception Bay, Newfoundland, extending from Jobs Cove (47°58.25'N, 53°01.10'W) in the north to Holyrood (47°23.30'W, 53°08.00'W) in the south (Fig. 1, Table 1). These beaches were sampled because capelin eggs were visible in the beach sediments and they were accessible from land. All samples were collected on July 8-9, 1983 with a 5.5 cm (inside diameter) depth-calibrated coring device (Frank and Leggett 1981). Cores were taken at each of the high-, mid-, and low-tide (HT, MT, LT) intertidal zones where egg deposition qualitatively 'judged' to be representative of the beach. The total depth of each core was recorded and the sample was preserved immediately in a 4% (by volume) formalin-seawater solution buffered with sodium borate.

ENUMERATION OF EGGS

Each core sample was rinsed thoroughly in fresh water over a 300 μm mesh sieve in the laboratory and then allowed to stand in a 2% (by weight) KOH solution for 24-36 hr in order to free the adhesive eggs from the beach sediments. Subsequently each sample was washed in fresh water and the majority of eggs were washed from the sediments, decanted, and filtered over a 300 μm mesh sieve. The remaining sediments were washed and settled in a ~75% glycerine-water solution and the remaining eggs were separated by floatation, decanted, and filtered. Two samples (Harbour Main: HT and MT) were lost and could not be included in the analysis.

Large organic particles (e.g. beach fly larvae, pieces of wood, etc.) were removed from the egg samples. A total of 13 samples and subsamples reflecting an increasing number of eggs (1,200-17,500) were then chosen and the total number of eggs in each were counted by hand and their number recorded. The displacement volume of each sample was measured using a 25 or 50 ml graduated cylinder (±0.25 ml). The relationship between egg number and displacement volume (ml) was calculated using linear regression analysis. Displacement volume was then measured for the remaining samples and egg number was estimated using the highly significant ($r^2 = 0.994$) volume (V) calibration (Fig. 2, Table 2):

(1) $$\text{Egg number} = 803.27\ (\pm 11.91)\ V \pm 422.17$$

Egg number was recorded for each sample and expressed as egg density (No./cm^3) for each core sample. The displacement volume technique additionally allowed for an estimate of the number of empty eggs (shells) in each sample (Table 1) because their lower bouyancy resulted in the shells settling last and above the previously settled eggs.

Depth standardized estimates of the areal density (No./cm³) of eggs in samples taken in each tidal zone (z) of each beach (b) were made by calculating:

(2) $$A_{zb} = \frac{T_{zb}\ (\bar{D}_b / D_{zb})}{CA}$$

where A_{zb} is the areal density, T is the total number of eggs counted in the sample, $\bar{D}_b$ is the average core depth (cm), D_{zb} is the recorded depth (cm) of the core, and CA is the area of the coring device (23.76 cm^2). The average areal density of eggs at each beach was expressed as the geometric mean of the areal density estimates to reduce the affect of over-dispersion (patchiness) on the estimates (Frank and Leggett 1981). Subsequently the total spawning deposition at each beach was estimated by multiplying the back-transformed geometric average density by the area of the beach.

BEACH MEASUREMENTS

Beach area was estimated from low altitude (~500 m asl) aerial photographs of each beach using a PLANIX-2 digital planimeter (±0.05 cm^2). The intertidal zone (beach area) was delineated by the low- and high-tide ridge marks clearly evident on each photograph. Extremely course-grained (rocky) areas that were unsuitable for spawning were easily indentified on the photographs and were excluded in the areal measurements. Photographic scale was calculated using the standard formula (see Avery 1968):

(3) $$RF = F/A$$

where RF is the natural scale, F is the camera focal length (151.98 mm) and A (mm) is the altitude from which the photograph was taken. Where areal photographs were unavailable (Avondale, Colliers), beach areas were estimated from a hydrographic chart (L/C 4565: scale 1:75,000). Beaches were classified according to their latitude and longitude and to their orientation normal to the shoreline resolved around 0° (negative values; west of N and positive values east of N).

ANALYSIS

Simple descriptive statistics (mean, variance etc.) were calculated for core depth, egg displacement volume, and egg density estimates. Relationships between the various beach descriptors and density estimates were assessed using analysis of variance (ANOVA) and bivariate and multivariate linear regression (SAS 1985). Distributional departures from normal were assessed with the W-statistic (Shapiro and Wilk 1965).

RESULTS

SPAWNING BEACHES

The beaches sampled covered a latitudinal range of 74 km along the west and southern coast of Conception Bay and their orientation ranged from -55° (305°) to 175° (Table 2). There was a positive relationship between beach orientation and latitude, reflecting the shape of Conception Bay and illustrating that the more southern beaches had a generally northerly orientation and northern beaches had a more easterly orientation (Fig. 3). Spawning beach area averaged 3268 m^2 and was highly variable (Table 4), ranging from 389 m^2 (Adams Cove) to 12127 m^2 (Coleys Point). The frequency distribution of beach area was log-normal.

CORE DEPTHS

Core depths of the 46 samles ranged from 7 to 16 cm, averaged 11.9 cm (Table 2), and were normally distributed (Fig. 5). Variation in core depth among intertidal zones (HT, MT, LT) was low (Table 2) and an analysis of variance for all beaches combined showed no significant difference in core depth among the three intertidal zones ($F = 0.67$, $p = 0.52$). There was an apparent but significant ($r^2 = 0.012$) decrease in average core depth with increasing latitude (Fig. 6). However, with the removal of three high-latitude beaches (Fig. 6: 12 = Spout Cove, 15 = Ochre Pit Cove, 16 = Jobs Cove) the relationship was significant ($r^2 = 0.47$, $p \leq 0.01$). Also, there was an apparent but insignificant ($r^2 = 0.07$) decreasing relationship between average core depth and beach orientation (Fig. 7). Again, with the removal of the high-latitude beaches the relationship was significant ($r^2 = 0.46$, $p \leq 0.01$). Although there was an increasing trend in average core depth with a logarithmic increase in beach area (Fig. 8) the relationship was not significant ($p \geq 0.05$).

EGG DENSITY

Eggshells represented an average 15% of the total egg and shell displacement volumes (Tables 2 and 3). The displacement volume of egg shells increased with the displacement volume of eggs in the majority of samples (Fig. 9), although there was a tendency for shells to represent a greater proportion of the total in the HT samples relative to the MT and LT samples. Many shells were collapsed or incomplete and resulted in a greater number of shells displacing a volume equivalent to fewer eggs. Therefore, total abundance estimates of shells were conservative.

Egg density averaged 46/cm^3, ranging between 3 and 127/cm^3 (Table 3). However, the frequency distribution of density estimates was clearly bimodal (Fig. 10); the first mode near 40/cm^3 represented the majority of the samples, and the second mode near 110/cm^3 represented samples collected at five beaches (Chapel Cove, Coleys Point, Bryants Cove, Broadhead Cove, and Ochre Pit Cove). Intertidal zone density estimates among beaches were not significantly different (ANOVA: $f = 1.68$, $p = 0.20$). The frequency distribution of the standardized areal density estimates (No./cm^3) showed a similar bimodal distribution (Fig. 11) and there was no significant difference in the intertidal zone estimates among beaches (ANOVA: $F = 1.64$, $p = 0.21$). The frequency distribution of the logarithmically transformed areal density (Fig. 12) was not significantly different from normal ($p = 0.12$). Analysis of variance showed no difference in the intertidal zone estimates among beaches ($F = 2.13$, $p = 0.13$). However, a least significant difference paired t-test indicated significant differences between MT and LT estimates ($p < 0.05$).

There was no significant relationships between the geometric average of the density estimates and beach orientation (Fig. 13), latitude (Fig. 14), beach area, and the logarithm of beach area (Fig. 15).

Multivariate linear regression analysis revealed no significant empirical relationships between either of mean density, geometric mean areal density, and areal density (dependent variate) and beach orientation, latitude, beach area and the logarithm of beach area (independent variates).

EGG DEPOSITION

Total egg deposition (eggs/beach) averaged 16.4×10^9 and ranged from ~1×10^9 eggs at Harbour Grace Island to ~80×10^9 eggs at Coleys Point (Table 4). Since the estimates were log-normally distributed (Fig. 16), the back-transformed geometric average of 8.8×10^9 eggs/beach was the best estimate of average egg deposition. As expected there was a significant relationship ($r^2 = 0.35$) between the logarithm of total egg deposition and average core depth (Fig. 17). There was, however no significant relationship between the logarithm of total deposition and beach orientation (Fig. 18), although the apparent dome-shape of the relationship indicated that deposition reached a maximum on beaches with a N to NE orientation. There was no relationship between the logarithm of total egg deposition and latitude (Fig. 19), but there was an apparent grouping of beaches within latitudinal zones, each showing a latitudinal decline in deposition within each of the four beaches (site 1-5, 6-10, 11-12, 13-16; see Fig. 1).

SUMMARY

1. There is no simple empirical relationship to predict egg density at the various beaches sampled for this study, although egg densities among beaches in Concption Bay appear to be related to beach orientation and to some extent with latitude.

2. Ochre Pit Cove, Job Cove, Bryants Cove, Chapel Cove, and Broadhead Cove had the greatest areal egg density.

3. Coleys Point, Ochre Pit Cove, Bryants Cove,and Spout Cove had the greatest total egg deposition.

4. Eggshells represented at least 15% of the total abundance of eggs and shells combined, and should not be ignored in estimating total spawning deposition. Though the estimates of eggshell abundance are conservative, we believe that the relative differences in abundance among beaches are accurate because of the relationship between egg and eggshell displacement volumes. We further suggest that the higher shell:egg ratio in the HT samples, relative to the MT and LT samples, can be attributed to a shorter hatching period in the HT zone (Frank and Leggett 1981) and to a greater loss of shells to the water column in the MT and LT zones because of their longer exposure to tidal inudation.

5. On the basis of the limited beach-stratified (3 samples/beach) collections made for this study the variation in egg density among beaches is greater

than the within beach variation. Therefore, where large-scale sampling is considered for a comparison among several beaches, the intertidal sampling location will not prevent the identification of among beach differences. However, for a single beach (Bryants Cove), an analysis of intertidal-zone samples collected using a random-stratified design with replication showed significant differences in egg density among the zones (Frank and Leggett 1981, Taggart unpub. data) and should be considered in beach sampling designs. When several beaches are to be sampled over a short period logistics will force a trade-off between the number of samples that can be collected on a single beach and the number of beaches sampled. Therefore sampling should be concentrated at one intertidal zone to optimize sampling within the zone and to facilitate among beach comparisons.

6. Log transformed estimates of beach area and of areal egg density should be used in evaluating relationships with other variables (e.g. capelin school area, number, and density, etc.).

7. It is very important to note that beach sediment grain size was not considered in this study. Capelin most frequently spawn on beaches with 0.5 to 2.5 cm grain size (Jangaard 1974). Future beach sampling programmes should include a measurement of grain size.

ACKNOWLEDGMENTS

K. Tallon and G. Mailett assisted in sample collections. E. Dalley kindly reviewed the manuscript and provided helpful comments. J. Lannon and M. Hynes assisted in the preparation of the manuscript. Analysis of the beach core samples was conducted by C.T.T. under Department of Fisheries and Oceans Contract 16SC-FP001-6-2139/01-SC.

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Tacle 1. Data values and summary statistics of orientation, latitude, longitude, coring depths, and displacement volumes for sixteen beach locations located along the western and southern coast of Conception Bay, Newfoundland.

NO.	SITE	ORIENT.	LATITUDE		LONGITUDE		CORE DEPTH (cm)			AVERAGE DEPTH	VOLUME EGGS (ml)			VOLUME SHELLS (ml)			VOLUME TOTAL (ml)		
		DEG.	DEG.	MIN.	DEG.	MIN.	HT	MT	LT	(cm)	HT	MT	LT	HT	MT	LT	HT	MT	LT
1	HOLYROOD	0	47	23.30	53	8.00	16.0	13.0	7.0	12.0	1.0	10.0	2.0	0.5	1.0	0.5	1.5	11.0	2.5
2	HARBOUR MAIN	25	47	25.90	53	9.65			14.0	14.0			16.5			3.5			20.0
3	CHAPEL COVE	30	47	26.15	53	9.10	13.0	11.0	9.0	11.0	39.0	26.3	10.0	4.3	3.0	1.5	43.3	29.3	11.5
4	AVONDALE	-45	47	26.80	53	10.40	14.0	13.0	12.0	13.0	11.5	8.5	7.0	2.5	2.0	1.0	14.0	10.5	8.0
5	COLLIERS	-55	47	27.80	53	12.60	9.5	15.0	15.0	13.2	15.0	11.0	2.3	4.5	1.0	1.0	19.5	12.0	3.3
6	COLEY'S POINT	50	47	34.60	53	15.90	14.0	14.5	9.0	12.5	14.0	41.0	9.3	2.0	4.0	0.5	16.0	45.0	9.8
7	SPANIARDS BAY	70	47	36.95	53	16.80	11.5	9.5	13.0	11.3	5.0	13.5	3.0	1.5	1.0	0.5	6.5	14.5	3.5
8	BRYANTS COVE (S)	55	47	40.45	53	11.35	11.0	10.5	14.0	11.8	16.0	32.0	23.0	3.0	4.5	2.5	19.0	36.5	25.5
9	BRYANTS COVE (N)	55	47	40.55	53	11.35	11.0	10.5	10.0	10.5	13.0	3.5	3.8	3.0	0.5	0.0	16.0	4.0	3.8
10	HRB GRACE ISLD	120	47	42.55	53	8.80	9.0	7.0	12.0	9.3	5.0	1.5	1.5	3.0	0.8	0.5	8.0	2.3	2.0
11	BRISTOLS HOPE	60	47	43.20	53	11.90	14.0	12.0	7.0	11.0	7.5	11.5	2.5	2.0	4.5	0.8	9.5	16.0	3.3
12	SPOUT COVE	90	47	49.15	53	7.65	16.0	15.0	14.0	15.0	11.0	19.0	7.0	3.3	2.0	1.0	14.3	21.0	8.0
13	BROADHEAD COVE	120	47	50.30	53	5.30	12.0	10.0	13.0	11.7	8.5	26.8	41.0	2.0	3.3	8.0	10.5	30.0	49.0
14	ADAMS COVE	90	47	51.60	53	5.30	9.5	8.0	9.0	8.8	13.0	11.5	5.5	2.5	3.5	2.5	15.5	15.0	8.0
15	OCHRE PIT COVE	20	47	54.65	53	4.10	11.0	13.0	15.0	13.0	14.0	35.5	52.5	2.0	6.0	4.0	16.0	41.5	56.5
16	JOB'S COVE	175	47	58.25	53	1.10	15.0	11.0	13.5	13.2	6.5	12.0	13.5	3.5	7.5	4.0	10.0	19.5	17.5
	N						15	15	16	46	15	15	16	15	15	16	15	15	16
	minimum						9.0	7.0	7.0	7.0	1.0	1.5	1.5	0.5	0.5	0.0	1.5	2.3	2.0
	maximum						16.0	15.0	15.0	16.0	39.0	41.0	52.5	4.5	7.5	8.0	43.3	45.0	56.5
	mean						12.4	11.5	11.7	11.9	12.0	17.6	12.5	2.6	3.0	2.0	14.6	20.5	14.5
	stdrd deviation						2.2	2.3	2.7	2.5	8.4	11.5	14.3	1.0	2.0	2.0	9.0	12.7	15.9
	variance						5.1	5.4	7.1	6.0	69.8	133.4	204.3	1.0	4.0	4.0	81.1	161.3	253.9
	coeff. variation						0.2	0.2	0.2	0.2	0.7	0.7	1.1	0.4	0.7	1.0	0.6	0.6	1.1

Table 2. Data values used in developing linear regression relationship to predict egg number from displacement volume of capelin eggs.

displacement volume (ml)	egg number	predicted number	upper 95% CL	lower 95% CL
1.5	1268	1205	1645	765
2.0	1092	1607	2053	1161
2.5	2075	2008	2460	1556
3.3	2184	2611	3071	2150
3.5	3102	2811	3275	2348
4.0	3836	3213	3683	2743
5.0	4567	4016	4498	3535
6.0	4904	4820	5313	4326
6.3	4368	5020	5517	4524
7.0	5110	5623	6128	5117
11.0	8736	8836	9389	8283
21.3	17472	17070	17745	16394
22.0	17472	17672	18356	16988

Regression Model:

Constant	0.000
Std Err of Y Est	422.168
R Squared	0.994
No. of Observations	13
Degrees of Freedom	12
X Coefficient(s)	803.271
Std Err of Coef.	11.908

Table 3. Data values and summary statistics of total number of capelin eggs and shells, density, depth standardized areal density, logarithm of areal density, and geometric mean density at sixteen beach locations located along the western and southern coast of Conception Bay, Newfoundland.

NO.	SITE	TOTAL NUMBER EGGS and SHELLS			DENSITY (no./cm3)			AVERAGE DENSITY (no./cm3)	STANDARDIZED DENSITY (no./cm2)			Ln STANDARDIZED DENSITY			GEOMETRIC MEAN DENS. Ln(No./cm2)	FINAL DENSITY EST. (No./cm2)
		HT	MT	LT	HT	MT	LT		HT	MT	LT	HT	MT	LT		
1	HOLYROOD	1205	8836	2008	3.17	28.61	12.08	14.62	38.0	343.3	144.9	3.64	5.84	4.98	4.82	123.69
2	HARBOUR MAIN			16065			48.30	48.30			676.2			6.52	6.52	676.21
3	CHAPEL COVE	34741	23496	9238	112.49	89.91	43.20	81.86	1237.3	989.0	475.2	7.12	6.90	6.16	6.73	834.68
4	AVONDALE	11246	8434	6426	33.81	27.31	22.54	27.89	439.5	355.0	293.0	6.09	5.87	5.68	5.88	357.59
5	COLLIERS	15664	9639	2611	69.40	27.05	7.33	34.59	913.8	356.1	96.5	6.82	5.88	4.57	5.75	315.45
6	COLEY'S POINT	12852	36147	7832	38.64	104.93	36.63	60.07	483.0	1311.6	457.9	6.18	7.18	6.13	6.50	661.95
7	SPANIARDS BAY	5221	11647	2811	19.11	51.61	9.10	26.61	216.6	584.9	103.2	5.38	6.37	4.64	5.46	235.54
8	BRYANTS COVE (S)	15262	29319	20483	58.40	117.53	61.58	79.17	691.1	1390.8	728.7	6.54	7.24	6.59	6.79	888.08
9	BRYANTS COVE (N)	12852	3213	3012	49.18	12.88	12.68	24.91	516.4	135.2	133.1	6.25	4.91	4.89	5.35	210.27
10	HRB GRACE ISLD	6426	1807	1607	30.05	10.87	5.64	15.52	280.5	101.4	52.6	5.64	4.62	3.96	4.74	114.38
11	BRISTOLS HOPE	7631	12852	2611	22.94	45.08	15.70	27.91	252.4	495.9	172.7	5.53	6.21	5.15	5.63	278.54
12	SPOUT COVE	11447	16869	6426	30.11	47.33	19.32	32.26	451.7	710.0	289.8	6.11	6.57	5.67	6.12	452.97
13	BROADHEAD COVE	8434	24098	39360	29.58	101.43	127.44	86.15	345.1	1183.4	1486.8	5.84	7.08	7.30	6.74	846.82
14	ADAMS COVE.	12451	12049	6426	55.16	63.39	30.05	49.54	487.3	560.0	265.5	6.19	6.33	5.58	6.03	416.87
15	OCHRE PIT COVE	12852	33336	45385	49.18	107.93	127.35	94.82	639.3	1403.1	1655.6	6.46	7.25	7.41	7.04	1140.93
16	JOB'S COVE	8033	15664	14057	22.54	59.94	43.83	42.10	296.8	789.2	577.1	5.69	6.67	6.36	6.24	513.19
	N	15	15	16	15	15	16	46	15	15	16	15	15	16	16	16
	minimum	1205	1807	1607	3	11	6	3.2	38.0	101.4	52.6	3.6	4.6	4.0	4.7	114.4
	maximum	34741	36147	45385	112	118	127	127.4	1237.3	1403.1	1655.6	7.1	7.2	7.4	7.0	1140.9
	mean	11755	16494	11647	42	60	39	46.6	485.9	713.9	475.5	6.0	6.3	5.7	6.0	504.2
	stdrd deviation	7233	10202	12800	25	35	37	34.2	287.9	430.8	462.4	0.8	0.8	1.0	0.7	296.6
	variance	5E+07	1E+08	2E+08	6E+02	1E+03	1E+03	1171.9	8E+04	2E+05	2E+05	0.6	0.6	0.9	0.5	87973.2
	coeff. variation	0.6	0.6	1.1	0.6	0.6	1.0	0.7	0.6	0.6	1.0	0.1	0.1	0.2	0.1	0.6

Table 4. Data values and summary statistics for aerial photography used in calculating spawning beach area and final estimate of the total spawning deposition.

NO.	SITE	AERIAL PHOTO SERIAL NO.	DATE	FOCAL LENGTH (mm)	ALTITUDE (m)	PHOTO SCALE 1:	PLANIMETRY AREA (cm2)	BEACH AREA (m2)	SPAWNING DEPOSITION (billions of eggs)
1	HOLYROOD	A-00001 131-132	23-6-83	151.98	457.2	3008.3	7.2	6516	8.06
2	HARBOUR MAIN	A-00002 205	26-6-85	151.98	396.2	2607.2	1.5	1020	6.89
3	CHAPEL COVE	A-00003 417	28-6-85	151.98	320.0	2105.8	2.8	1242	10.36
4	AVONDALE	ESTIMATED FROM	TOPOGRAPHIC MAP		(L/C 4565.	1:75000)		1500	5.36
5	COLLIERS	ESTIMATED FROM	TOPOGRAPHIC MAP		(L/C 4565.	1:75000)		3000	9.46
6	COLEY'S POINT	A-00001 126-127	23-6-83	151.98	457.2	3008.3	13.4	12127	80.27
7	SPANIARDS BAY	2 04 128	22-6-86	153.23	487.7	3182.7	6.2	6280	14.79
8	BRYANTS COVE (S)	A-00001 123	23-6-83	151.98	457.2	3008.3	2.3	2036	18.08
9	BRYANTS COVE (N)	A-00001 123	23-6-83	151.98	457.2	3008.3	1.4	1222	2.57
10	HRB GRACE ISLD	A-00003 398-399	28-6-85	151.98	320.0	2105.8	1.7	754	0.86
11	BRISTOLS HOPE	A-00001 107	23-6-83	151.98	457.2	3008.3	5.2	4706	13.11
12	SPOUT COVE	A-00001 11	19-6-83	151.98	457.2	3008.3	4.2	3801	17.22
13	BROADHEAD COVE	R3 4594	26-6-84	151.98	457.2	3008.3	0.5	452	3.83
14	ADAMS COVE	A-00002 342	28-6-85	151.98	335.3	2206.1	0.8	389	1.62
15	OCHRE PIT COVE	R2 4361	25-6-84	151.98	457.2	3008.3	5.7	5158	58.85
16	JOB'S COVE	A-00001 83	23-6-83	151.98	457.2	3008.3	2.3	2081	10.68
	N						14	16	16
	minimum						0.5	389.3	0.9
	maximum						13.4	12126.7	80.3
	mean						3.9	3267.8	16.4
	stdrd deviation						3.3	3021.1	21.1
	variance						11.2	9E+06	444.2
	coeff. variation						0.8	0.9	1.3

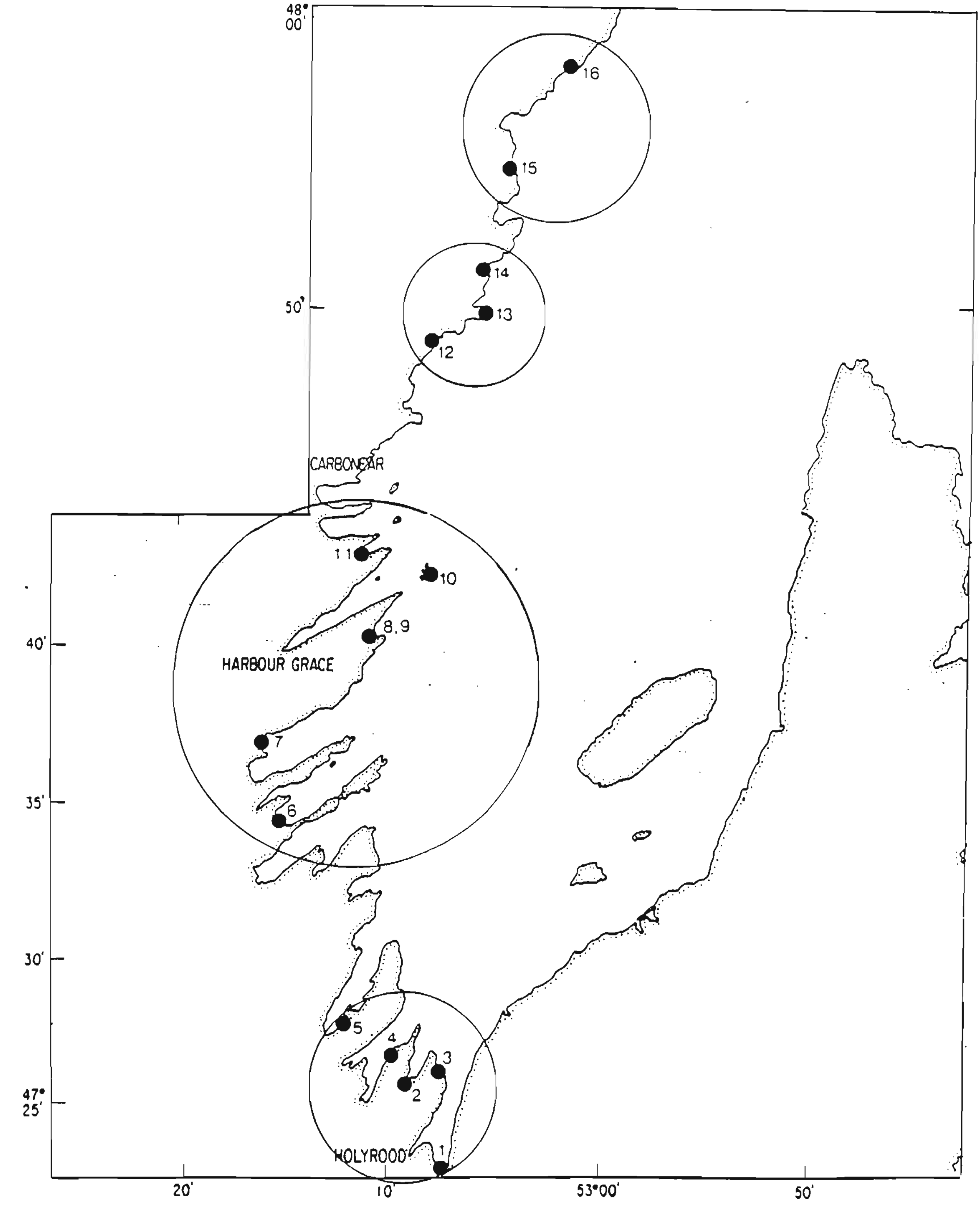

Figure 1. Map of Conception Bay showing the location of the 16 spawning beach sites sampled in 1983. Location names are listed in Table 1. Site groupings according to total egg deposition and latitude (see text) are circled.

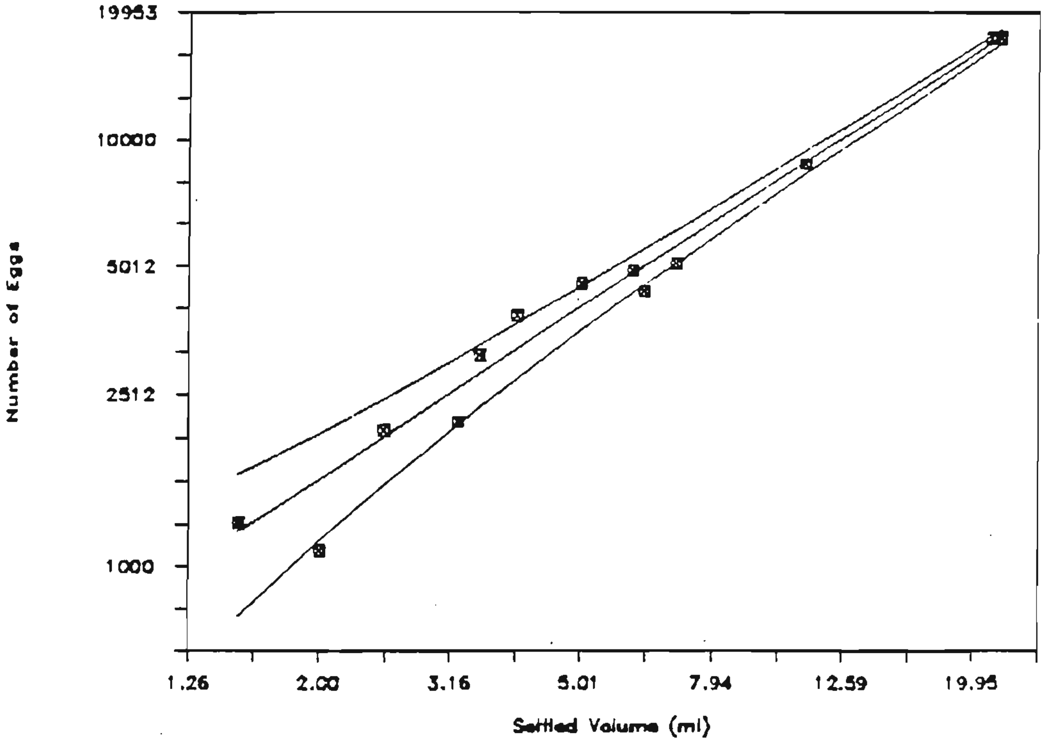

Figure 2. Log plot of the linear regression relationship (±95% CI) between capelin egg number and displacement (settled) volume.

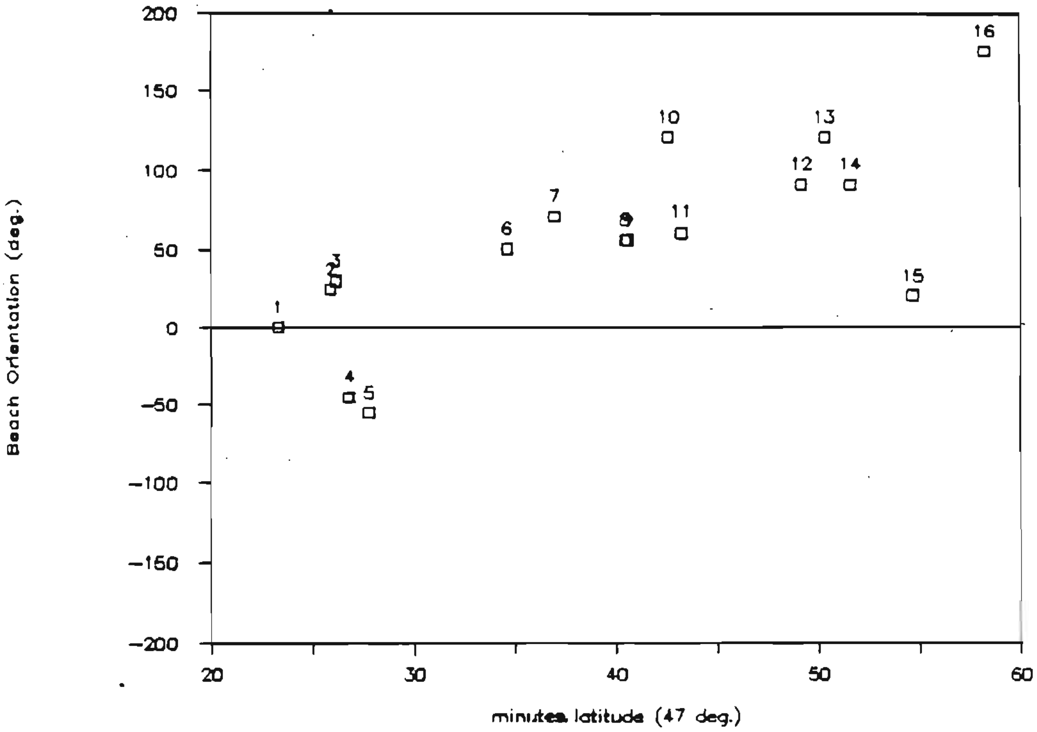

Figure 3. Scattergram of the relationship between beach orientation (normal to shore; negative values W of N) and latitude (minutes at 47°N).

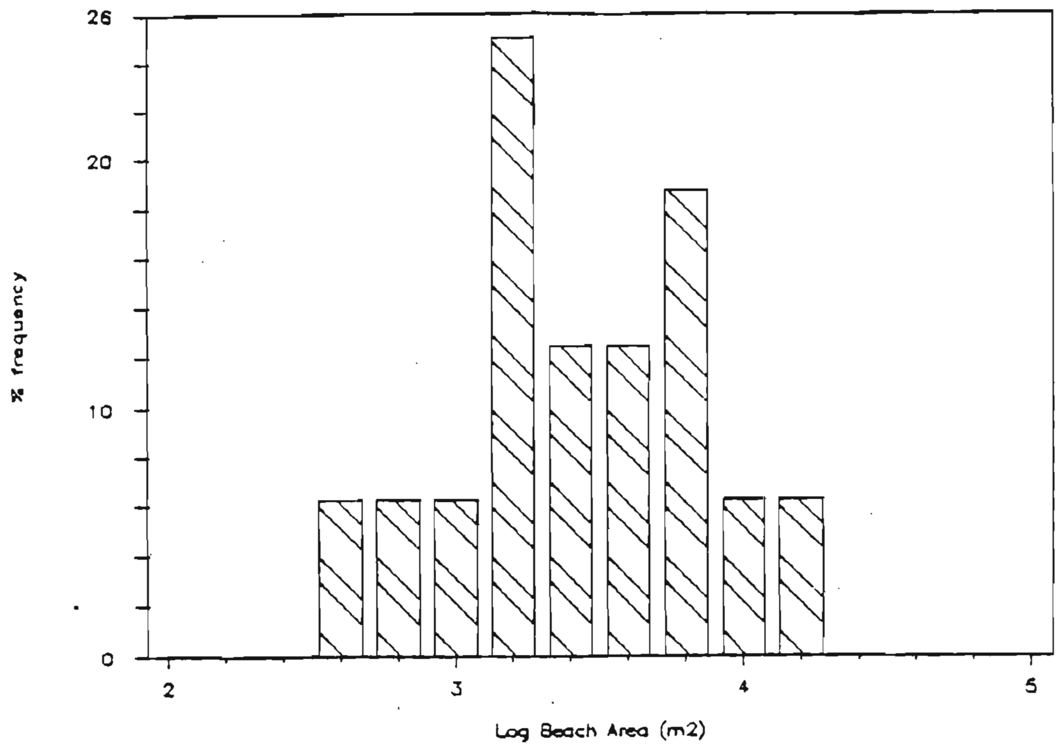

Figure 4. Log-normal frequency distribution of spawning beach area for 16 beaches in Conception Bay.

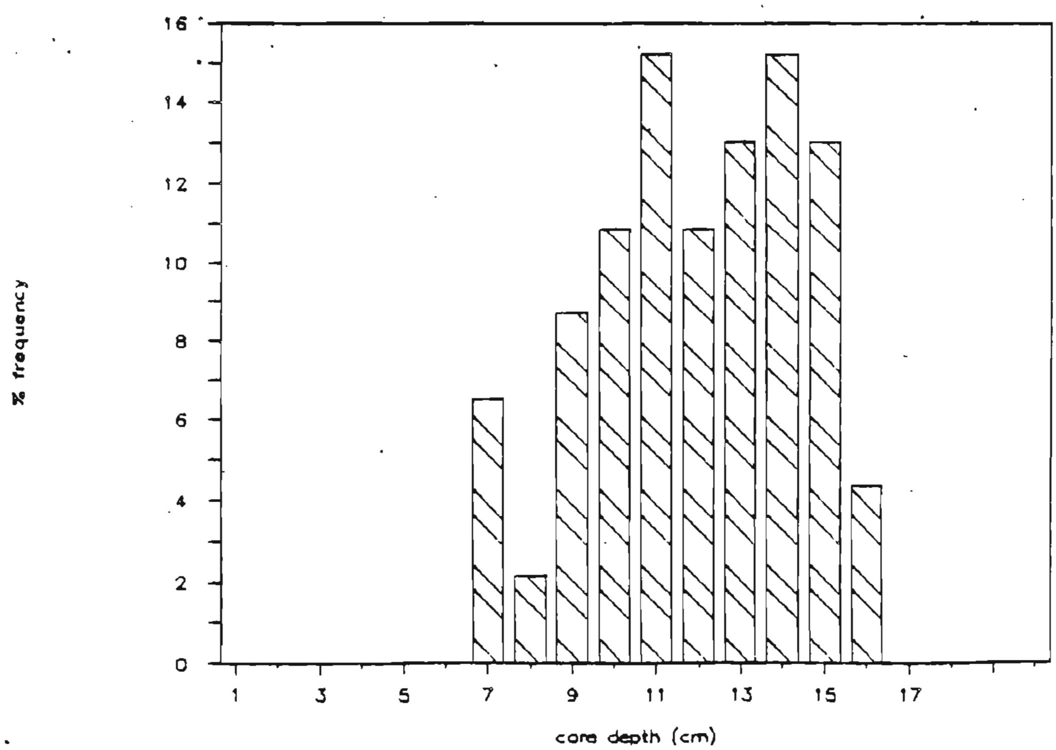

Figure 5. Frequency distribution of beach core depth for 16 beaches in Conception Bay (n=46).

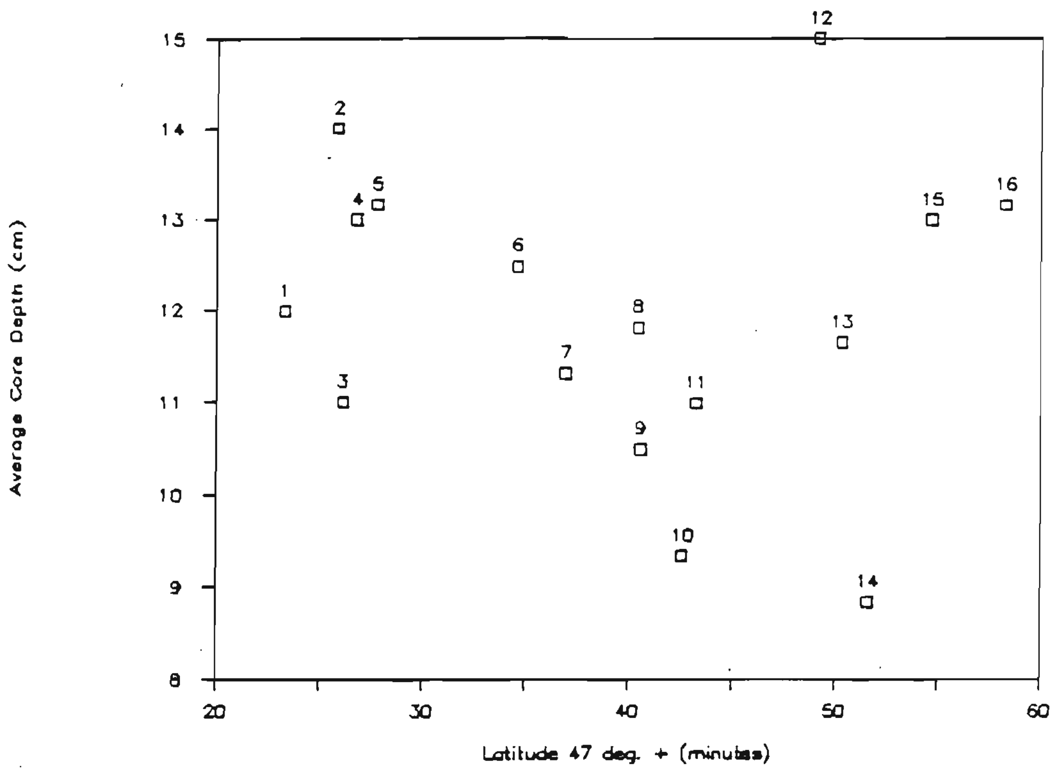

Figure 6. Scattergram of the relationship between average beach core depth and latitude (minutes at 47°N). Each datum refers to a location number (see Table 1).

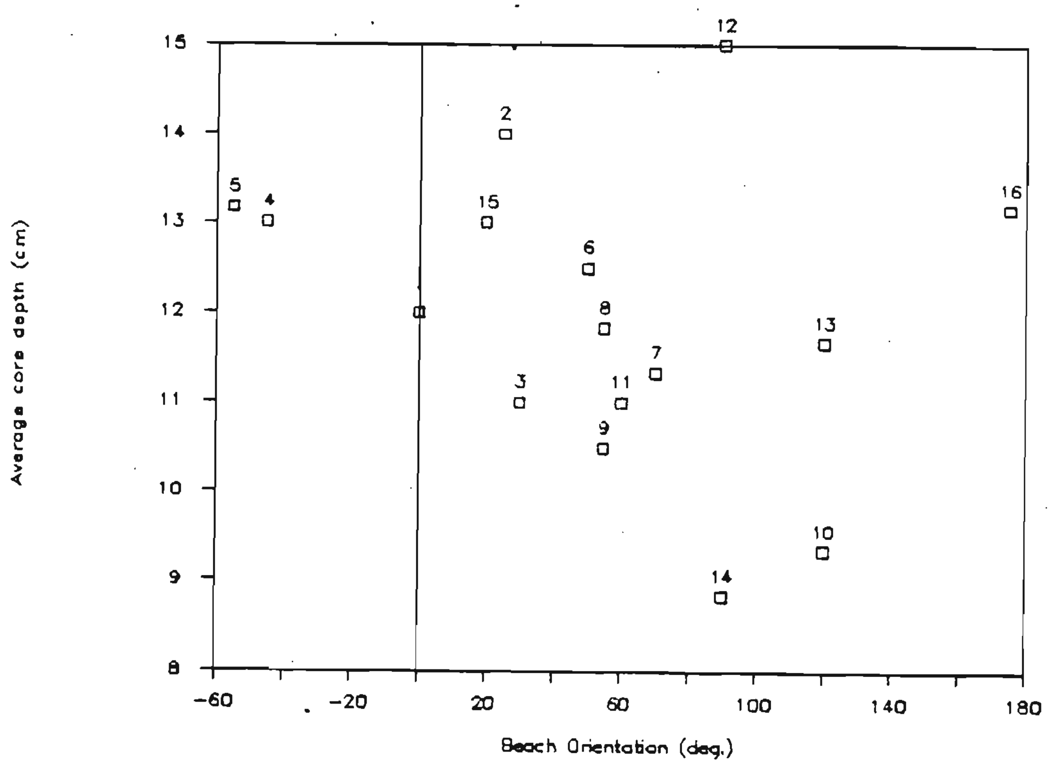

Figure 7. Scattergram of the relationship between average beach core depth and beach orientation (normal to shore; negative values W of N). Each datum refers to a location number (see Table 1).

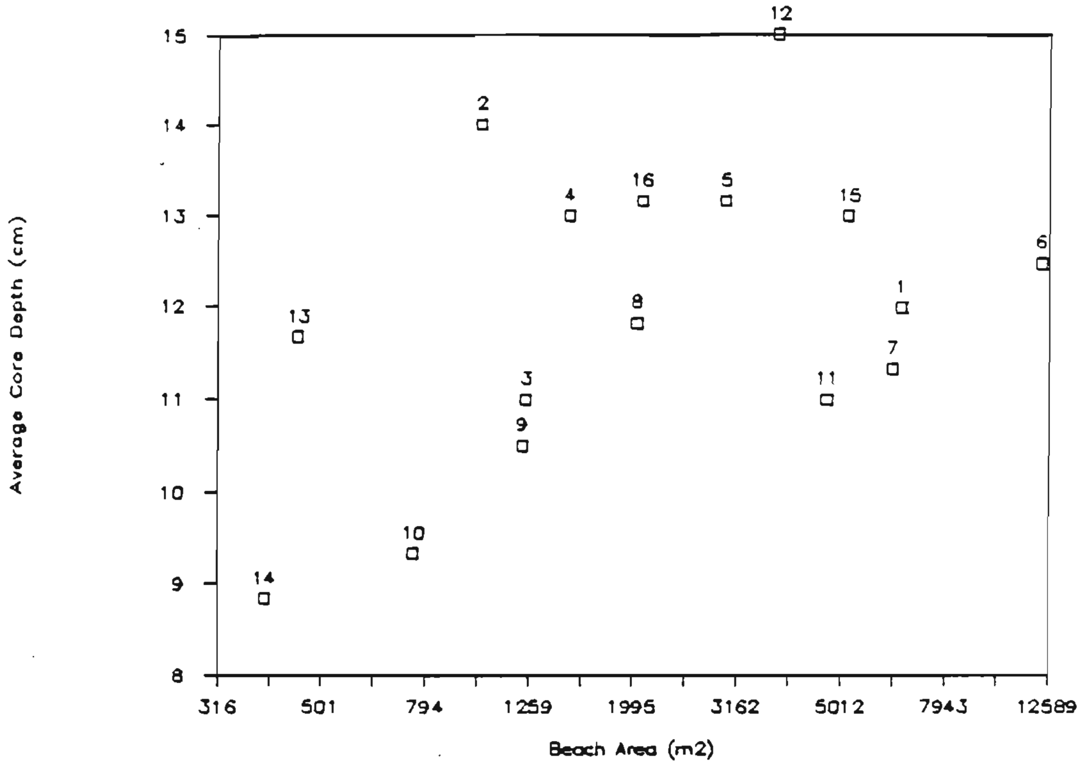

Figure 8. Semi-log scattergram of the relationship between average beach core depth and beach area. Each datum refers to a location number (see Table 1).

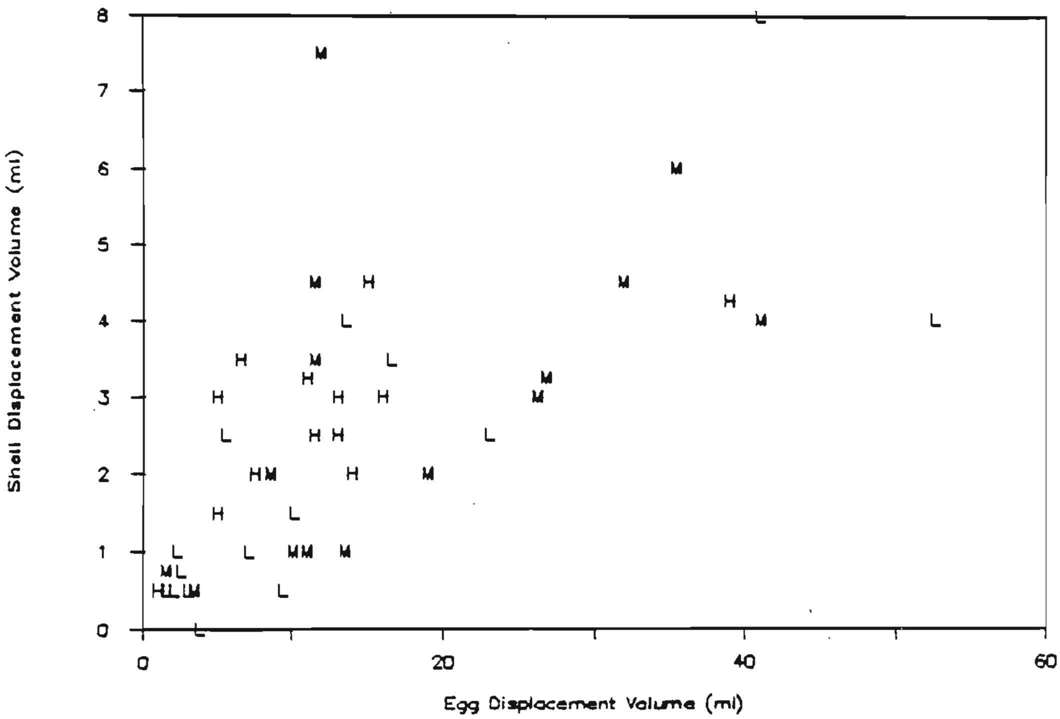

Figure 9. Scattergram of the relationship between displacement volume of egg shells and eggs. Samples taken in the high-, mid-, and low-tide are noted H, M, and L, respectively.

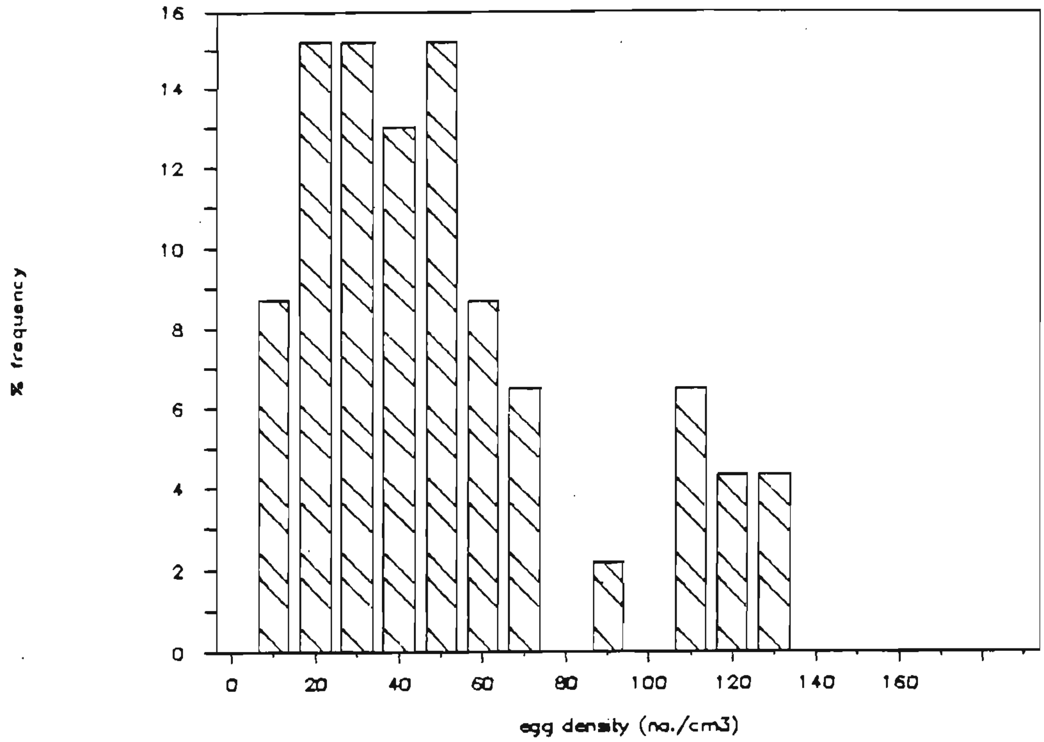

Figure 10. Bimodal frequency distribution of egg density estimates from 46 core samples.

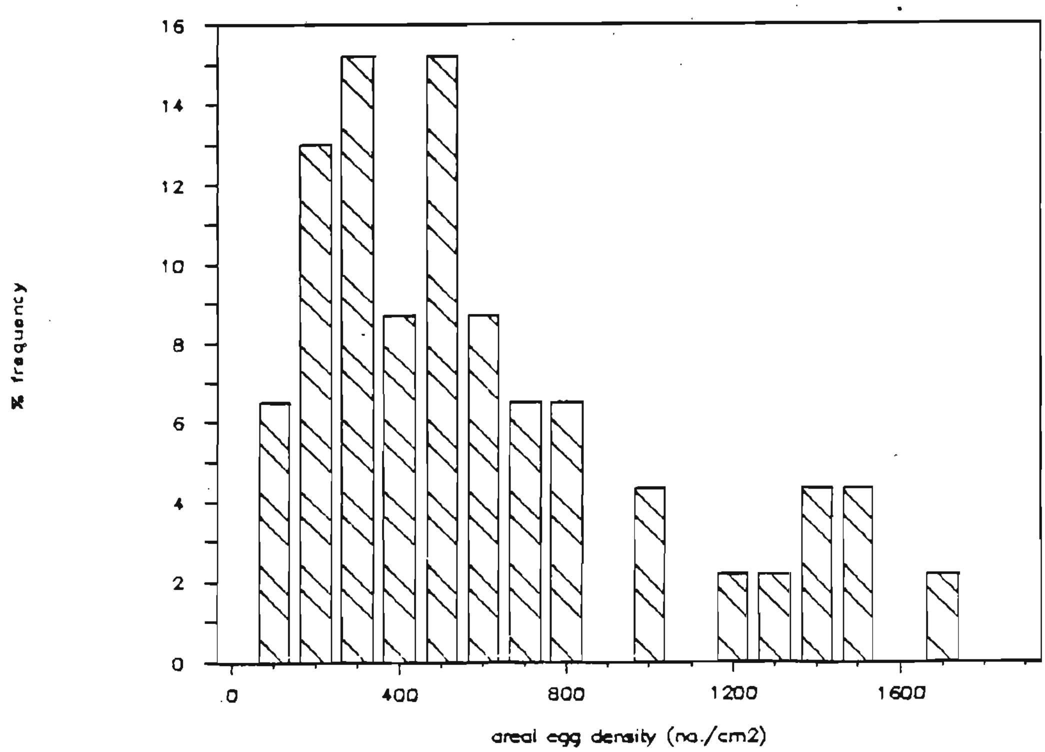

Figure 11. Bimodal frequency distribution of standardized areal egg density estimates from 46 core samples.

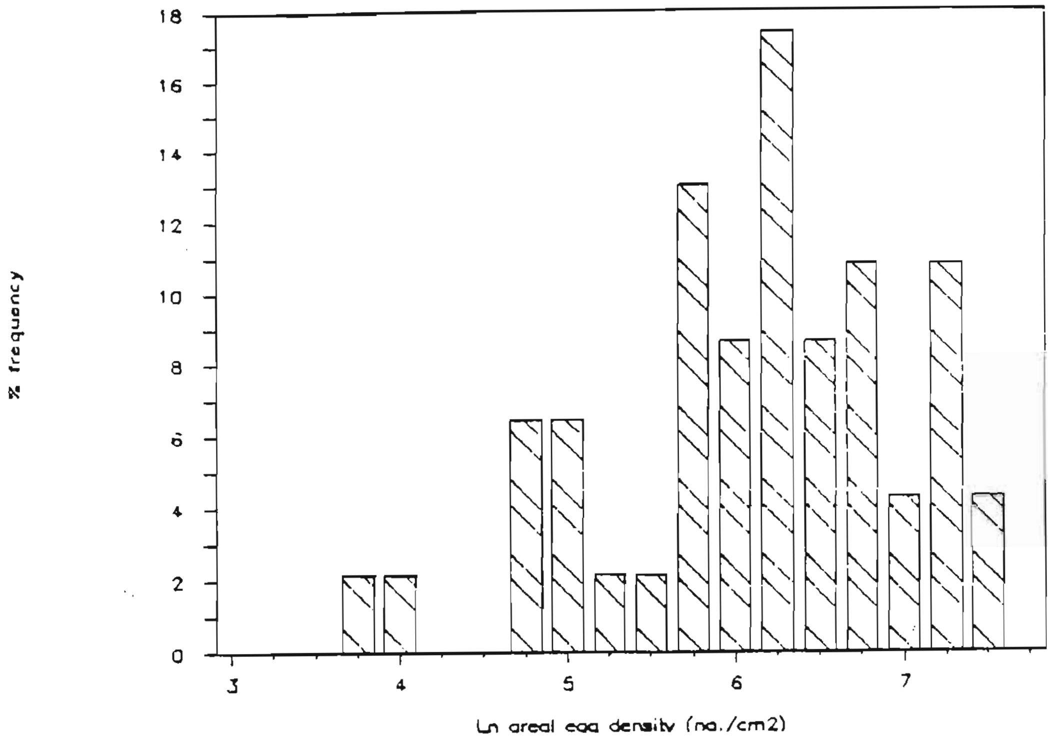

Figure 12. Frequency distribution of the log transformed standardized areal egg density estimates from 46 core samples. The distribution is not significantly different from normal (p=0.123).

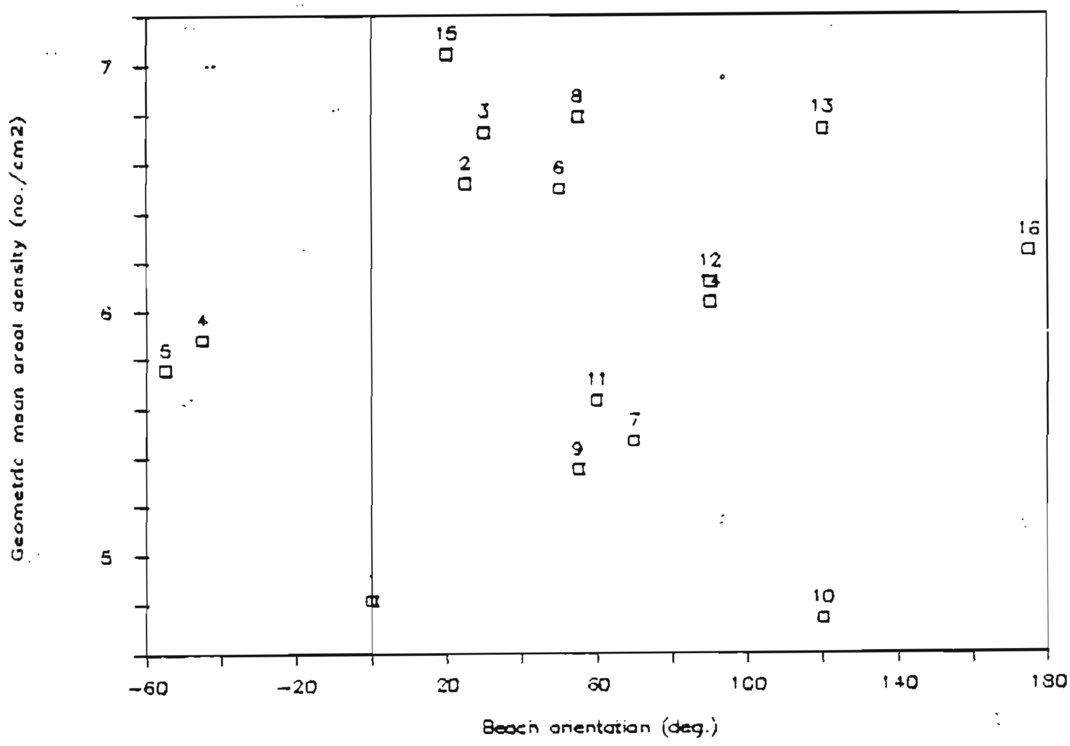

Figure 13. Scattergram of the relationship between the geometric average areal egg density and beach orientation (normal to shore; negative values W of N). Each datum refers to a location number (see Table 1).

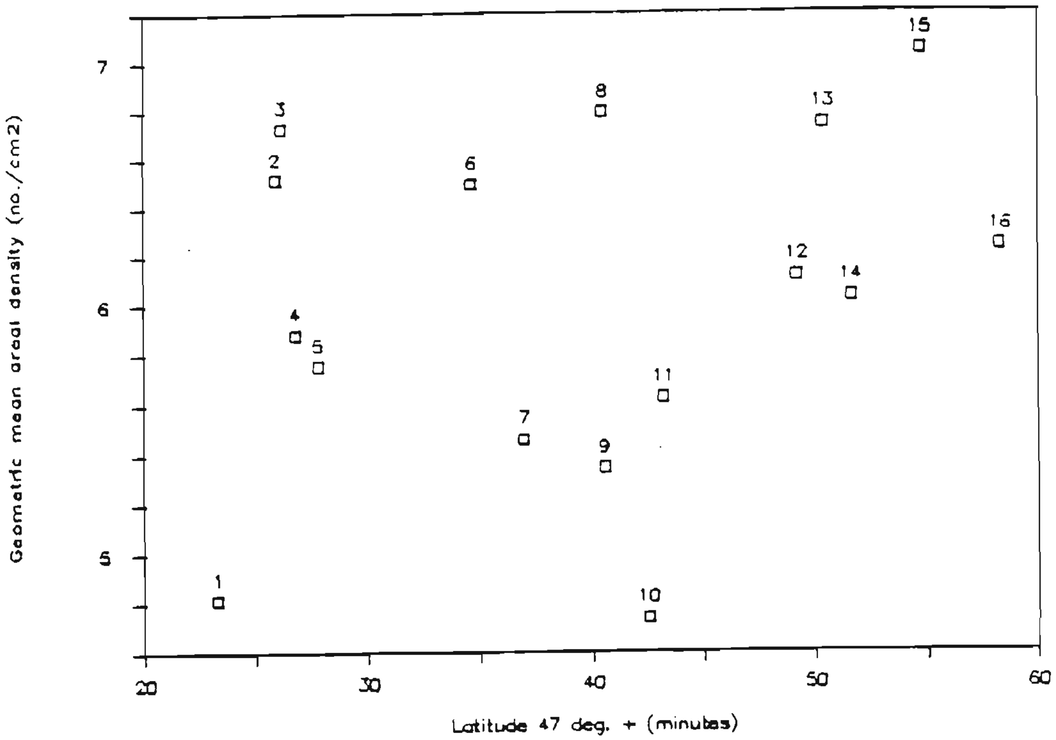

Figure 14. Scattergram of the relationship between the geometric average areal egg density and latitude (minutes at 47°N). Each datum refers to a location number (see Table 1).

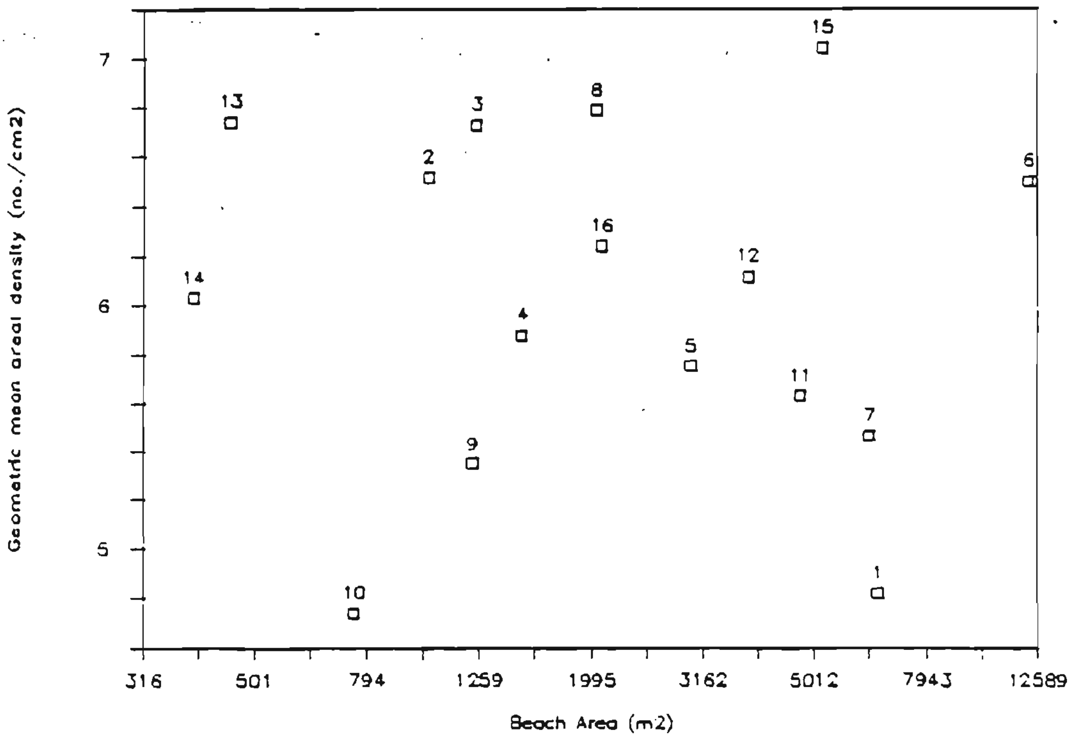

Figure 15. Scattergram of the relationship between the geometric average areal egg density and beach area (log axis). Each datum refers to a location number (see Table 1).

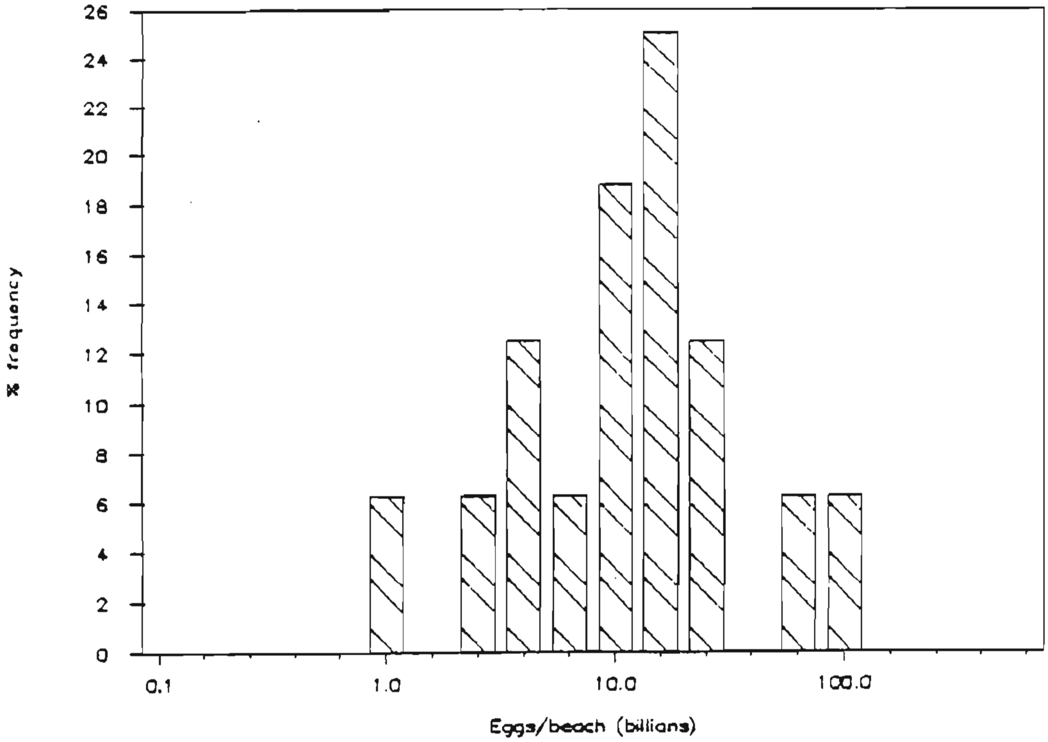

Figure 16. Log-normal frequency distribution of total egg deposition for 16 beaches in Conception Bay.

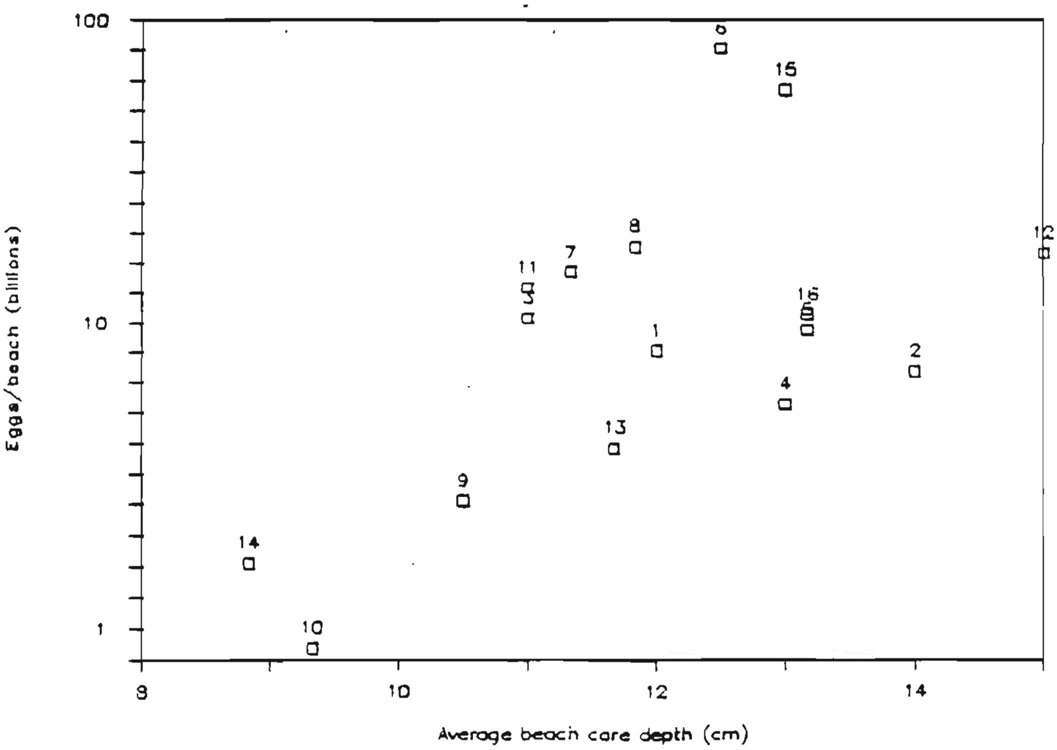

Figure 17. Semi-log scattergram of the relationship between total egg deposition and average beach core depth. Each datum refers to a location number (see Table 1).

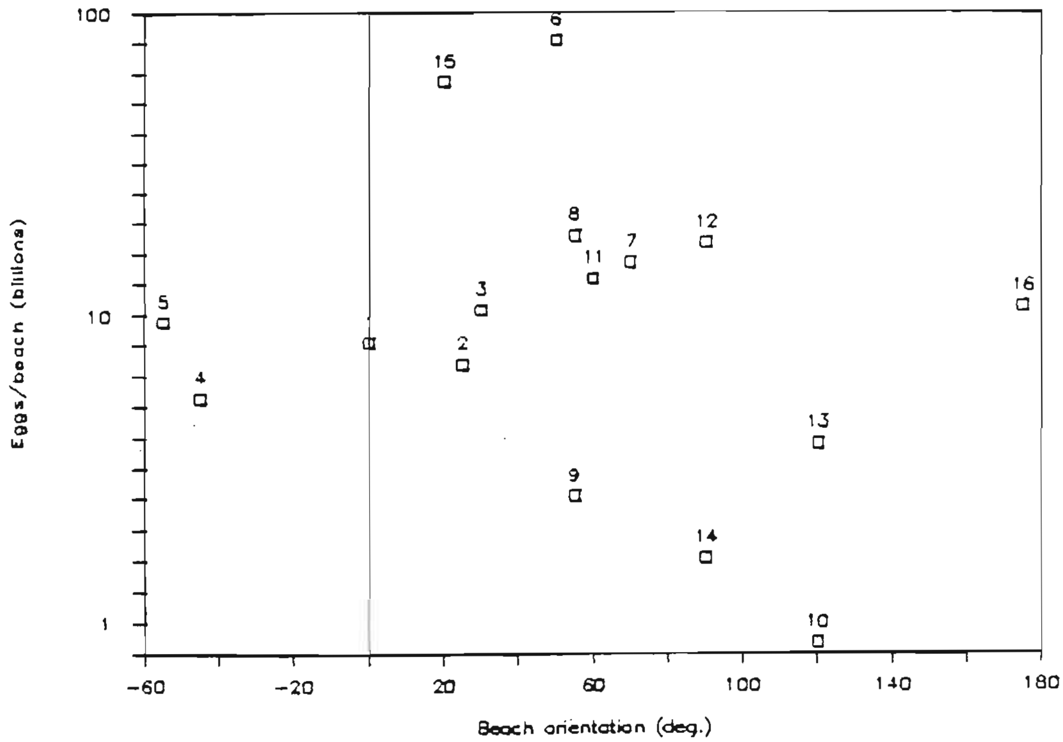

Figure 18. Semi-log scattergram of the relationship between total egg deposition and beach orientation (normal to shore; negative values W of N). Each datum refers to a location number (see Table 1).

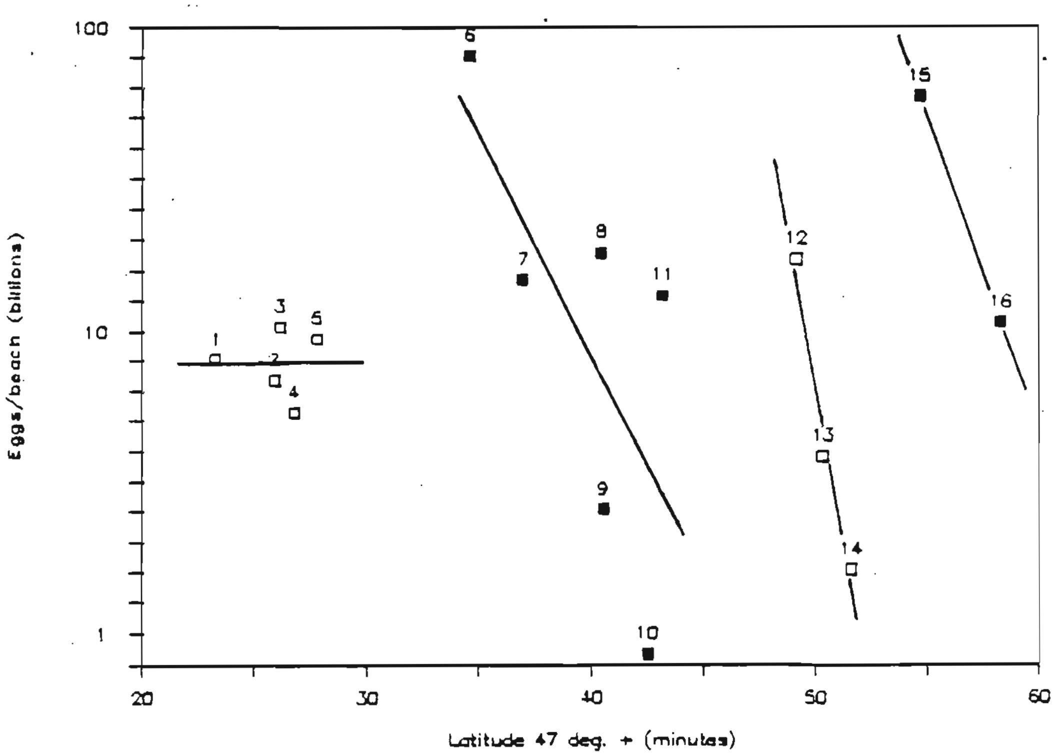

Figure 19. Semi-log scattergram of the relationship between total egg deposition and latitude (minutes at 47°N). Each datum refers to a location number (see Table 1). Line of best-fit for each of the apparent geographic groupings (see Fig. 1) is shown.